Chapter II

SAFE PRACTICES IN THE USE OF SOLVENTS

> "Safety . . . is teamwork between management and labor, between foreman and his crew, between operators and maintenance men, between one man and his buddy working alongside of him. It's the company providing the safest equipment and the employees providing the safest attitude."
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> W. C. Uhl, *Petroleum Processing* **3**, 211 (1948).

As is well known, organic solvents are among the most commonly used chemicals in industry today. Some fifty years ago, the number of solvents employed and their relative quantities were rather small. Today, tons of a large variety of alcohols, ethers, ketones, petroleum and coal tar distillates, halogenated hydrocarbons, etc., are employed each year in all kinds of industries, such as lacquer, paint and varnish, plastics, dry cleaning, textile, printing, plating and many others.[1]

While all of these solvents are invaluable to modern industry, it must be recognized that solvents in general, like other chemicals and tools in general, are potentially hazardous. Nevertheless, just as an apparently safe operation or what is considered a non-hazardous chemical may cause accidents and death, so a most dangerous operation and a very toxic chemical may be employed with safety if adequate consideration is given to the proper handling of the potential danger. Thus solvents, even toxic solvents, can be handled with safety.

The search is still on for the "ideal" industrial solvent which does not burn, does not explode, does not cause dermatitis, is not toxic, and dissolves the greatest number of industrially employed inorganic and organic substances, including fats and oils. Until it has been discovered and made commercially available, we must take suitable precautions in the employment of solvents available at present.

According to Gordon,[2] a well-planned safety program for the safe handling of solvents consists of:

1. Identification of hazardous operations.
2. Analysis of the hazards.
3. Engineering controls.
4. Personal protection of employees.
5. Medical protection.
6. Supervision.
7. Employee education.

Identification of Hazardous Operations

Occasionally a hazard has been discovered only after it has caused some more or less serious after-effects, but this is rarely the case today. Nowadays, information on the hazards of commonly employed industrial volatile solvents can be obtained very readily from the

[1] For a comprehensive tabulation of industrial uses of solvents, see T. C. Gregory, *Uses and Applications of Chemicals and Related Materials.* Reinhold, New York, 1939, 1944.

[2] L. Gordon, *Materials & Methods* **24**, 90 (1946).

literature, the manufacturers of solvents, local, state and federal industrial hygiene agencies, Underwriters' Laboratories, Factory Mutual Laboratories, some insurance companies, Industrial Hygiene Foundation, American Industrial Hygiene Association, American Medical Association, etc. Suitable plans can then be made for safe handling and proper controls.

It should be kept in mind, however, that American manufacturers often send out samples of new chemical products for experimental purposes before the completion of studies of all significant properties of the new material. In such cases, it is the custom to print an appropriate cautionary statement on the label which usually reads as follows: "The chemical, physical, and toxicological properties of this product have not yet been fully investigated and the handling or use may be hazardous. Exercise due care."

Several large manufacturers have toxicological laboratories which test each new chemical synthesized so that its relative toxicity is known before it is adopted for manufacture on a commercial scale. This knowledge of the relative toxicity of a new synthetic organic chemical permits its classification as to degree of toxicity and hence the precautions to be observed in its utilization.

The initial step should be a thorough survey of the plant to determine which solvents are used, when, where, how much, and how frequently. Such a survey must include all regular operations, the occasional overhauling of equipment, the cleaning of machinery, the disposal of solvent wastes, the storage and distribution of solvents, and the transfer of solvents to different containers and to various departments throughout the plant.

As a rough guide, the following classification of solvents patterned after that of MacGee, Weber, and Senter[3] is designed for laboratory and plant purposes. It classifies the solvents on the basis of their potential health hazard.

[3] A. E. MacGee, L. J. Weber, and C. H. Senter, *J. Am. Oil Chemists' Soc.* **25**, 279 (1948).

A. 1. Solvents which can be considered relatively harmless or which seldom cause injuries to the workmen's health after long association with them in everyday plant routine:

pentanes	mineral spirits
petroleum ether	ethyl alcohol
petroleum benzine	ethyl chloride
hexanes	ethyl ether
heptanes	ethyl acetate

2. Solvents which, even though considered to be somewhat toxic, because of their low volatility and usual conditions of use are seldom dangerous from a practical point of view:

ethylene glycol butyl glycol
dibutyl phthalate

B. Solvents which can be considered mildly hazardous or which can be endured by workmen for a short time within maximum permissible concentrations without serious disturbances or dangerous after-effects:

toluene	trichloroethylene
xylene	perchloroethylene
cyclohexane	ethylene oxide
cumene	hydrogenated cyclic naphthas
cycloheptane	tetrahydronaphthalene
propyl acetate	nitroethane
amyl alcohol	
amyl acetate	
butyl alcohol	

C. Solvents which can be considered as definitely hazardous or which cannot be endured by the workmen for even a short time except at extremely small concentrations without possibility of dangerous after-effects or injuring the ability to work:

benzene	formaldehyde
carbon disulfide	phenol
carbon tetrachloride	nitrobenzene
methyl alcohol	dimethyl sulfate
tetrachloroethane	pentachloroethane

Analysis of the Hazards

In ordinary industrial operations in which organic solvents are involved, the worker may come in bodily contact with the liquid solvent or may inhale some of the vapors, either for a short time or for the whole working period. Although there are solvents which have only a very slight vapor pressure under ordinary conditions and, therefore, give off only low concentrations of vapors under these conditions, there are others which have an appreciable vapor pressure at room temperature and usually are readily recognizable by their odor. These latter solvents are commonly called "volatile" solvents. Typical examples of "nonvolatile" and "volatile" solvents are glycerol and acetone, respectively. It should be recognized that in the case of these volatile solvents there is the added potential hazard of the effect of solvent inhalation. Depending upon the nature of the solvent as well as the human element, exposure to solvents, both volatile and nonvolatile, may or may not cause illness. It has been pointed out that "the health hazard problem of industrial solvents can be separated into two parts, the one consisting of the relatively easy problem of protecting workmen against exposure to solvent liquid and extremely large concentrations of solvent vapor, and the other consisting of the relatively difficult problem of protecting workmen against exposure to comparatively small concentrations of solvent vapor or gas in the laboratory or plant atmosphere." Methods of taking care of these various health hazards are discussed later.

Physiological Response

When vapors or gases are inhaled, they pass into the general circulation and are distributed to the heart and the central nervous system with a rapidity second only to that which occurs when they are injected into the veins. They can produce either a general toxic action without harm to the respiratory tract or a mixed effect, being generally toxic and locally irritant. Some vapors or gases act so violently in the upper respiratory system and lungs that their general toxic effects are secondary considerations. With few exceptions, all volatile solvents if inhaled in sufficient concentration for sufficient length of time are detrimental to health.

Occasionally, because of accidental spillage, carelessness, ignorance, or sabotage, the amount of vapor in the atmosphere may be extremely high and far above the maximum allowable concentration. Such an acute exposure may cause unconsciousness or even death if the individual is not promptly removed to an uncontaminated atmosphere and given proper medical attention.

Chronic Exposure.—Chronic exposure, i.e., repeated exposure or exposure for long periods of time to concentrations above the maximum allowable concentration values but below concentrations which cause discomfort rapidly, may first cause mild symptoms such as headache and fatigue, then nausea, intestinal, visual, or mental disturbances, and, finally, injuries to the blood, liver, kidneys, or other organs of the system.

Classification of Physiological Action. The physiological action of the industrial solvents is classified by Flury[4] under five main headings:

(1) General nerve poisons without other distinctly specific poisonous effects; to this group belong the primary alcohols (with the exception of methyl alcohol), ethers, aldehydes, ketones, and certain esters, and benzine.

(2) Lung poisons or irritants, that is, those substances which induce the phenomenon of inflammation in the tissues with which they come into immediate contact; the principal rep-

[4] K. B. Lehmann and F. Flury, *Toxikologie und Hygenie der technischen Loesungsmittel.* Springer, Berlin, 1938; (translated by) E. King and H. F. Smyth, Jr., *Toxicology and Hygiene of Industrial Solvents.* Williams & Wilkins, Baltimore, 1943. See also Morris B. Jacobs, *The Analytical Chemistry of Industrial Poisons, Hazards, and Solvents.* 2nd Ed., Interscience, New York, 1949.